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PROTECTING EXPOSED ENDS OF TIMBER BEAMS IN THE PUGET SOUND AREA

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ABSTRACT

When heavy timber members are fully exposed to the weather, changes in moisture content caused by the action of sun and rain are appreciable. This exposure is most severe on end-grain surfaces which absorb moisture rapidly. Stresses in beams of large sections usually cause checking, staining, and degradation of finishes. In the rainy climate of the Puget Sound area, moisture contents in the wood readily reach levels at which decay occurs, and even pressure-treated timbers may decay if deep checks allow water to penetrate to untreated material in the interior.

Finishes, flashings, and protective covers may be used to reduce these effects; and experimental evaluations of many potential protective methods are needed to identify systems which provide satisfactory durability and minimize maintenance. This report describes weather exposure tests of 12 protective methods, with observations of moisture content and appearance over a 3-year period. One finishing system and two types of protective covers appear to provide adequate protection.

KEYWORDS: Moisture barriers (wood), wood as building material, finishes (wood).

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INTRODUCTION

When heavy timber beams extend outside a building to support an overhang or are used in open structures such as walkways, they are usually protected from the elements by the overhang. A fascia board may be used to provide partial cover at the ends, and the lower portion may be cut back at an angle to avoid direct exposure to sun and rain (fig. 1).

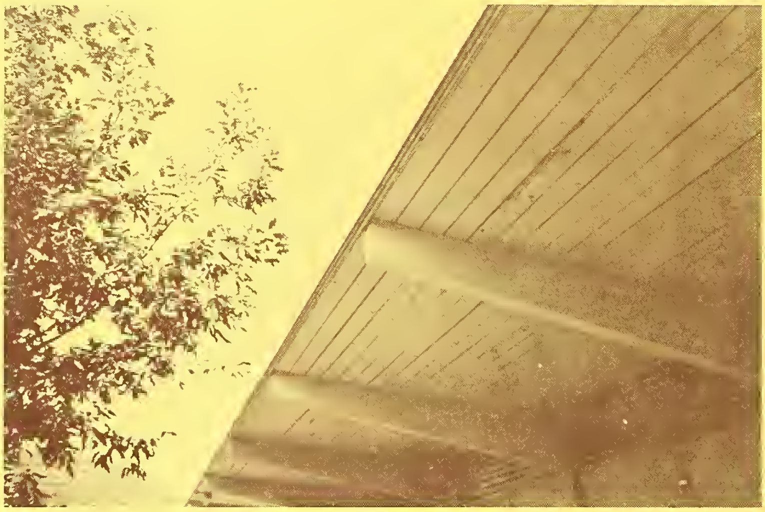

Figure 1.--Tapering of overhang exposes minimum end section.

These measures are usually adequate to limit exposure of the vulnerable ends so that extreme weathering effects do not occur. However, in many cases, designers prefer to extend the square end of a beam to the fascia or even well beyond the overhang protection. This may be done to support sunshades or other functional framing or simply to emphasize the massive ends of large sections.

This practice presents a severe weathering problem, frequently resulting in early damage to the wood and to applied finishes. Clear coatings deteriorate rapidly in direct sunlight, and no commercially available clear coating is fully effective in preventing moisture change in the wood. Moisture changes cause appreciable dimensional changes in large timber sections, usually resulting in considerable checking on ends and top surfaces. These checks, in turn, admit more water, sometimes causing blistering and flaking of the finish and a badly stained and discolored surface (fig. 2). In addition, the wood is weakened by excessive moisture which may reach levels at which decay occurs. Decay frequently occurs in warm, moist climates; and irreparable damage may result. Severe exposures require protective systems which need little or no maintenance, since access may be difficult or costly.

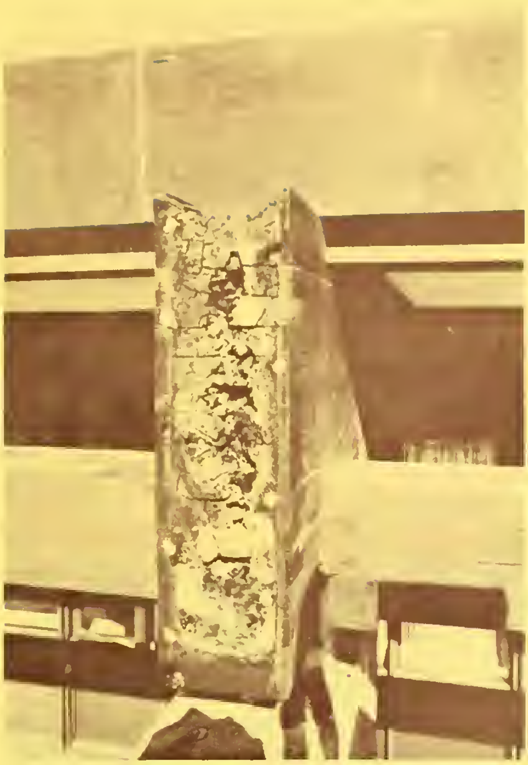

Figure 2.--Decay in an exposed beam end in the Northwest.

Finishes

Problems attending the complete exposure of heavy timbers may be minimized by application of one of a variety of finishes and coatings. Unfortunately, those transparent enough to show the wood grain are less effective in retarding moisture changes and less durable under solar exposure. Frequent refinishing is required to maintain transparent finishes, and surface coatings such as varnish often must be completely removed before satisfactory refinishing can be achieved. Recent practice has favored use of penetrating stains which can be readily refinished without removal. These may contain a preservative and a moisture repellant, and their durability varies with the type and amount of pigment included, the porosity of the wood, and the number of successive applications. However, stains, whether semitransparent or solid color, oil-base or latex-base, are not effective in excluding moisture vapor.

Opaque coatings such as paint can be colorful and attractive, even though they conceal the natural wood grain. Solvent-thinned coatings of good quality, when applied in two or three coats over a suitable primer, are durable coatings with good resistance to moisture, both liquid and vapor. Maintenance may not be required for from 5 to 10 years, depending on location and orientation. Some of the better quality water-thinned paints (latex paints such as the acrylics and vinyl-acrylics) may be even more durable than the better solvent-thinned paints, but they form open or porous films. Consequently, they are not effective in excluding water and moisture vapor from wood.

Finishes are primarily decorative, however, and the protection they provide to heavy timber sections is limited in degree and time. They require maintenance to continue their protective function; and maintenance is frequently inadequate, inexpert, or nonexistent.

Flashings

Durable, waterproof covers or flashings can be provided at beam ends to exclude rainwater from the absorbent end-grain surfaces and to protect top surfaces. Such covers also reflect solar heat, greatly reducing moisture content changes and protecting applied finishes.

One type frequently used is a conventional metal flashing, custom formed to cover top and end surfaces. Metal covers may be simple and functional, painted to blend with the wood, or they may be used as decorative accents in a wide variety of shapes and natural metal colors, from bright stainless steel to the dull gray of zinc-titanium alloys, the many anodized colors of aluminum, and copper and brass (fig. 3). Decorative accents in metal are hardly new in architecture; they were frequently used in the temples of the Far East before the time of Christ, lending charm as well as cover.

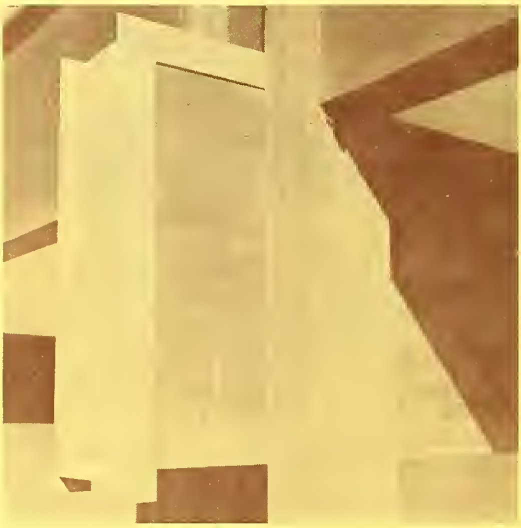

Figure 3.--Decorative metal end cap.

Thoughtfully designed metal flashings can be effective in excluding water and reducing the effects of solar heat, but some existing flashings are inefficient or self-defeating. It is essential that flashings cover the top as well as the ends of a projecting member and be well lapped or counterflashed where the top edge of the beam intersects the roof or wall. An adequate drip-edge should be provided to shed water from the top away from side surfaces, and a drip-edge at the end should extend well below the bottom surface to prevent windblown rain from feeding into end grain at the bottom. It is believed desirable to set the entire flashing on blocking to provide a ventilating airspace between beam and flashing, allowing the wood to "breathe" and avoiding direct contact with condensation which may form on the metal under some conditions. A completely airtight sleeve covering side and bottom surfaces of the beam should be avoided, since this would serve to contain any moisture already in the beam as well as conceal any damaging effects.

Wood cover plates are simple and attractive alternatives to metal flashings but present another set of practical difficulties. Where thin boards are used, warping is common, causing a crack to open at one or more edges where water can enter and be contained by capillarity. Because the boards are usually short, splits develop easily either after stress from the fasteners or by deformation due to moisture changes. Thin plywood plates are a better choice, since the tendency to split is eliminated and a better balance of grain reduces the tendency to split is eliminated and a better balance of grain reduces the tendency to warp or cup. Cupping is not eliminated in plywood exposed to the weather, however, and there is still a need for firm attachment to restrain any imbalance and prevent the opening of edge cracks. Nailing a plywood plate into the end grain of the beam is no solution, as it leaves a crack all around the edge which will almost certainly enlarge in time.

As with metal flashings, plywood plates must cover any exposed top surface of the beam as well as the end-grain (fig. 4). This reduces checking on the top surface and keeps water out of any checks which occur, but it also provides an opportunity to cover the joint at the end plate and provide a drip-edge all around.

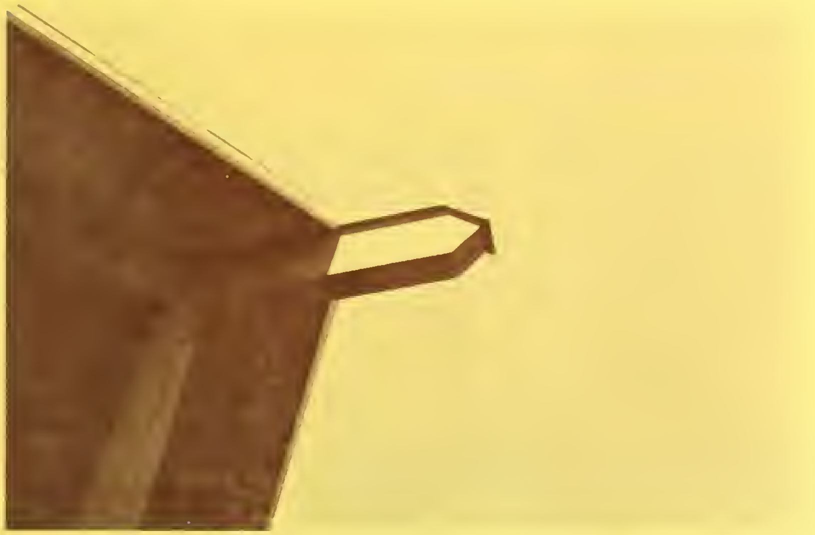

Figure 4.--Plywood plates furnish cover and shade for the beam.

The best method of attaching the plywood plates appears to be a waterproof adhesive. Although many adhesives are unsuitable for field application or for use on relatively coarse end-grain surfaces, the recent development of elastomeric construction adhesives provides a simple method of application with an easily obtainable material with promising characteristics. Elastomeric adhesives are now available in cartridges for convenient application in the field, and they can be uniformly spread with a notched linoleum trowel. They can be applied over a wide range of temperatures.

Other possible coverings include many of the durable plastic or composite sheets, provided they can be adequately formed or joined. Durable plastic coating systems, with or without reinforcing, are now available as waterproof membranes for roofing and waterproofing. These membranes can be made to conform to any shape and are available in a range of colors. Membrane systems based on Neoprene, Hypalon, Silicone, and vinyl are among those commercially available. A deterrent to their use might be the specialized application involved, but on new work the roofing contractor usually could include such flashings in his contract, as well as metal flashings.

Previous Research

The U.S. Forest Products Laboratory, Madison, Wisconsin, has long been active in the evaluation and development of finishes for wood. Recent exposure tests of paint systems applied to laminated beam sections at Olympia, Washington, confirm the durability of several commercially available paints over 8 years. These systems, consisting of combinations of aluminum or other zinc-free primers with two top coats of either titanium-lead and oil or acrylic emulsion paint, effectively protected the samples over the test period. Checking in the samples was minor, and little deterioration of the finishes was observed. It should be noted, however, that these laminated samples were relatively small in section, about 6 by 7 inches. Much larger laminated sections are now in common use, and the magnitude of dimensional changes increases with the size of the section. Thus, these tests do not adequately predict the performance of paints on much larger sections, where small changes in moisture content cause relatively larger changes in dimensions which may rupture the coating.

CURRENT TESTS

To extend our knowledge of finishes on larger sections and to evaluate several types of flashings, the Environmental Wood Use project in Seattle has initiated a comparative study at its exposure site near Olympia, Washington. A total of 24 glulam Douglas-fir blocks 6-3/4 by 18 by 29 inches long, bonded with waterproof adhesive, were obtained from an American Institute of Timber Construction qualified laminator. Laminations were standard 2-inch nominal thickness, as normally used in straight members, and grain direction was random. Each block was moisture-sealed at one end with hot asphalt, so only the opposite end and side surfaces could absorb moisture, simulating the exposed end of a longer laminated beam. A moisture sensor[1] was placed 3 inches from the unsealed end at approximately the midheight of the section, and a thermocouple was placed near the sensor in a control sample to measure the temperature within the wood when moisture content readings were made. Each pair of blocks consisted of laminations from separate lumber layups to assure that grain characteristics were not similar in the two blocks, and each pair was treated with a coating, paint system, or flashing. In November 1971, eight pairs of samples were prepared under cover and set out on racks at the exposure site; and in November 1972, four additional pairs were prepared and placed, for a total of 12 pairs of blocks, each pair having a different treatment, as indicated in table 1. Moisture contents of the samples at the time of placement varied from 7 to 9 percent. Figure 5 shows how the 24 samples were placed on a continuous rack horizontally and about 24 inches above the ground, with the treated end facing south.

Figures 6 and 7 show details used for all plywood covers and for the metal cap flashings.

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[1] J. E. Duff. A probe for accurate determination of moisture content of wood products in use. USDA Forest Service Research Note FPL-0142, 10 p., illus. 1966.

Table 1--*Protective methods used on samples*

Sample	Type	Sealer or primer	Finish or flashing
1A 1B	Controls -- stain	Water-repellent penta, all surfaces	One coat semitransparent acrylic stain
2A 2B	Acrylic paint	Water-repellent penta, plus acrylic primer	Two coats brown acrylic paint
3A 3B	3/8-inch plywood Neoprene	Water-repellent penta, side surfaces only	3/8-inch unfinished redwood plywood covers, top and end, Neoprene bonded
4A 4B	Timberlab varnish	Water-repellent penta, all surfaces	Three coats Timberlab British Experimental Varnish
5A 5B	Polyurea paint	One coat resin sealer, all surfaces	Two coats white resin paint
6A 6B	Vinyl with glass fiber	One coat vinyl primer on flashing area	One layer 16-mesh glass fiber cloth; two coats vinyl resin over fabric
7A 7B	3/8-inch plywood Silicone	Water-repellent penta, side surfaces only	3/8-inch unfinished redwood plywood covers top and end, Silicone bonded
8A 8B	Metal flashing	Water-repellent penta, all surfaces	One coat acrylic stain, all surfaces; zinc-titanium alloy flashing
9A 9B	Acrylic varnish	One coat clear acrylic sealer, all surfaces	Two coats clear acrylic varnish
10A 10B	Neoprene coating	Water-repellent penta, side surfaces only	Elastomeric Neoprene adhesive, troweled on top and end surfaces
11A 11B	1/2-inch plywood Neoprene	Water-repellent penta, side surfaces only	1/2-inch stained Douglas-fir plywood covers, top and end, Neoprene bonded
12A 12B	1/2-inch plywood Silicone	Water-repellent penta, side surfaces only	1/2-inch stained Douglas-fir plywood covers, top and end, Silicone bonded

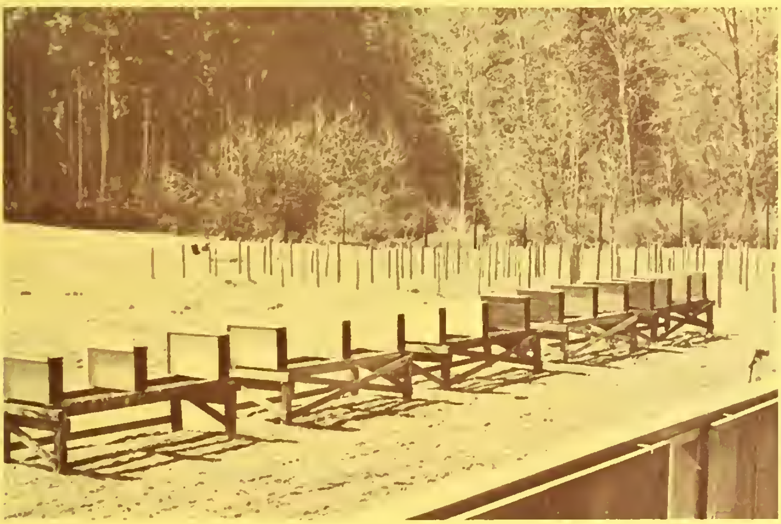

Figure 5.--Partial view of samples on rack, showing asphalt sealed ends.

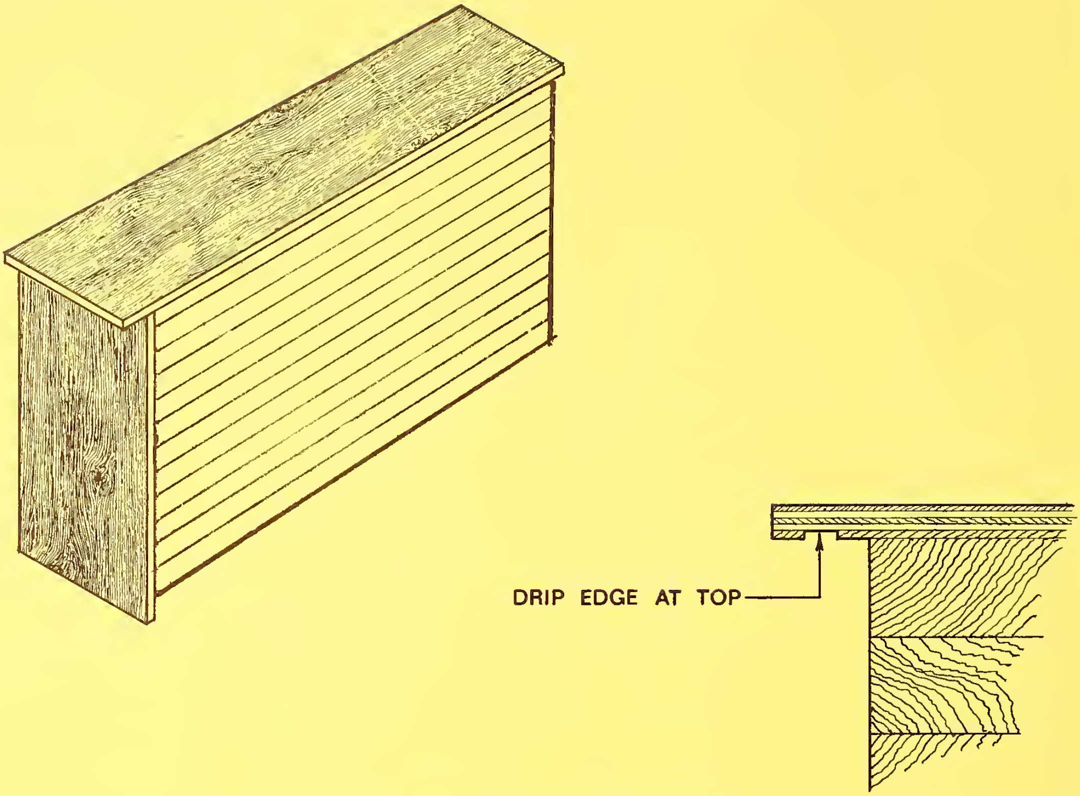

Figure 6.--Plywood covers.

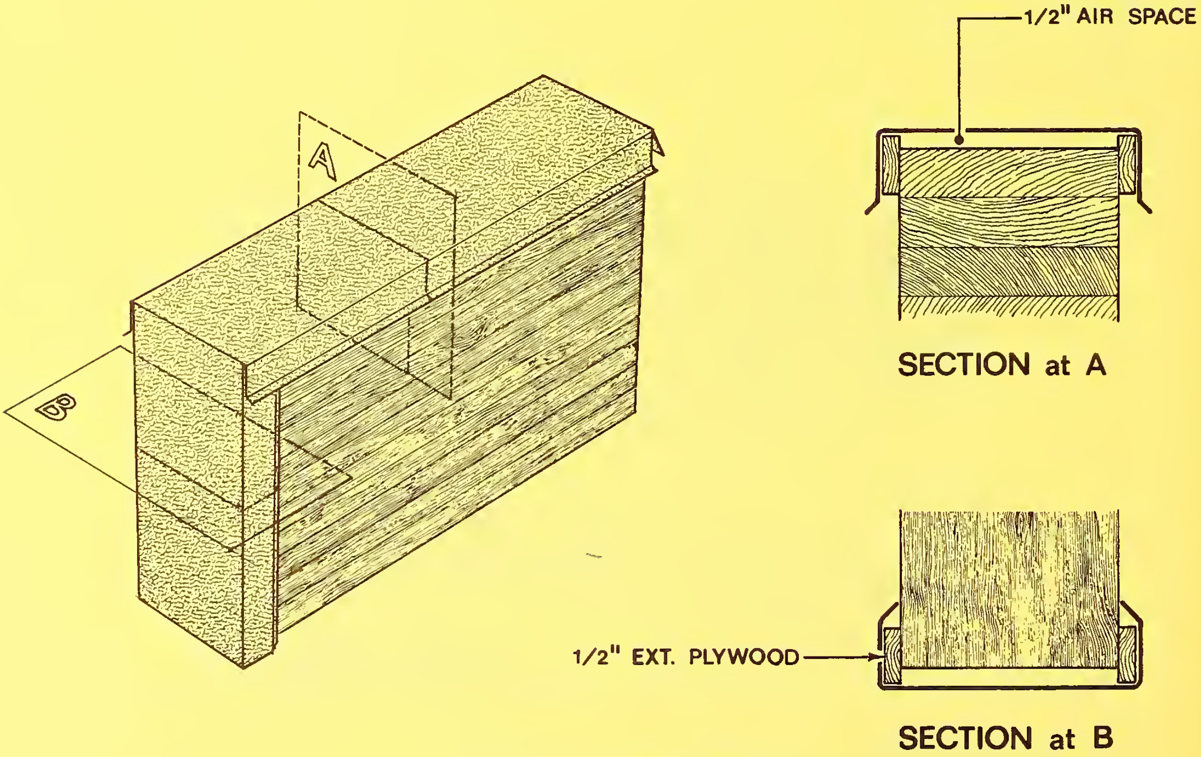

Figure 7.--Metal caps.

OBSERVATIONS AND DISCUSSION

Samples were examined on a monthly or bimonthly basis the first year, but this frequency was found to be unnecessary and the interval was extended to semiannually the second year and reduced again to approximately quarterly the third year. During each observation, moisture contents of all samples were recorded (table 2), and photographs were taken of any significant changes in appearance. Readings omitted from the table on samples 1B and 6B result from an initially insufficient supply of moisture sensors. Other omissions indicate readings that appeared erratic by the action of the meter or were believed influenced by local moisture concentrations.

The effects of weathering on an inadequately protected beam end may be seen in figures 8, 9, and 10, where the considerable stresses occurring are clearly evident in the progression of checks and splits in the surfaces over a short period of time. These are the control samples, finished with light pigmentation and were expected to deteriorate rapidly. In terms of appearance and moisture content, failure may be said to have occurred in 4 months, with continued subsequent deterioration over the next 18 months.

The acrylic paint samples, 2A and 2B (table 1), performed only a little better, with some end checking appearing after 4 months and large top and side checks developing in 5 more months.

This paint system probably would have performed better if a more effective vapor barrier, such as several coats of aluminum paint, had been substituted for the acrylic primer.

Table 2--*Percent moisture content of beam samples*[1/]

Sample	Treatment	Reading date														
		Feb. 1972	Mar. 1972	Apr. 1972	June 1972	Aug. 1972	Sept. 1972	Nov. 1972	Apr. 1973	June 1973	Aug. 1973	Nov. 1973	Mar. 1974	June 1974	Sept. 1974	Mar. 1975
1A	Controls--	18	24	19	16	12	11	11	--	17	--	30	30	35	9	35
1B	stain	--	--	--	--	--	--	--	--	25	--	45	65	65	13	50
2A	Acrylic	17	17	17	13	11	11	11	--	20	--	22	40	40	13	25
2B	paint	9	11	10	10	9	9	9	--	11	--	12	22	19	10	19
3A	3/8-inch plywood	18	19	19	15	8	6	7	--	9	--	8	11	14	10	8
3B	Neoprene	45	40	25	8	7	7	7	--	8	--	30	30	30	30	19
4A	Timberlab	25	25	22	30	30	35	22	--	12	--	8	--	--	6	12
4B	varnish	8	10	8	9	7	6	19	--	9	--	23	23	10	7	19
5A	Polyurea	8	10	7	8	8	8	7	--	9	--	9	9	9	9	--
5B	paint	8	14	8	8	8	9	8	--	9	--	10	10	10	10	11
6A	Vinyl with	8	10	10	12	11	12	11	--	14	--	13	15	16	15	18
6B	glass fiber	--	--	--	--	--	--	--	--	16	--	45	9	--	7	8
7A	3/8-inch plywood	10	12	12	12	11	11	11	--	13	--	12	13	14	11	13
7B	Silicone	10	13	12	13	12	12	12	--	10	--	12	14	15	11	14
8A	Metal	12	13	12	11	9	8	10	--	10	--	10	11	10	7	11
8B	flashing	13	19	17	13	9	8	12	--	12	--	17	25	10	7	13
9A	Acrylic	--	--	--	--	--	--	--	10	12	10	40	40	16	6	11
9B	varnish	--	--	--	--	--	--	--	11	14	10	40	30	19	13	30
10A	Neoprene	--	--	--	--	--	--	--	13	14	12	40	30	21	11	25
10B	coating	--	--	--	--	--	--	--	13	15	15	55	40	40	14	35
11A	1/2-inch plywood	--	--	--	--	--	--	--	19	15	12	12	14	14	11	14
11B	Neoprene	--	--	--	--	--	--	--	12	14	12	11	14	15	11	15
12A	1/2-inch plywood	--	--	--	--	--	--	--	23	17	13	13	16	16	12	15
12B	Silicone	--	--	--	--	--	--	--	13	13	12	21	13	14	7	8

[1/] Readings below 25 percent have been rounded to the nearest whole number; 25 percent and above, to nearest 5 percent. Readings omitted on samples 1B and 6B result from an initially insufficient supply of moisture sensors; other omissions indicate readings that appeared erratic by the action of the meter or were believed influenced by local moisture concentrations.

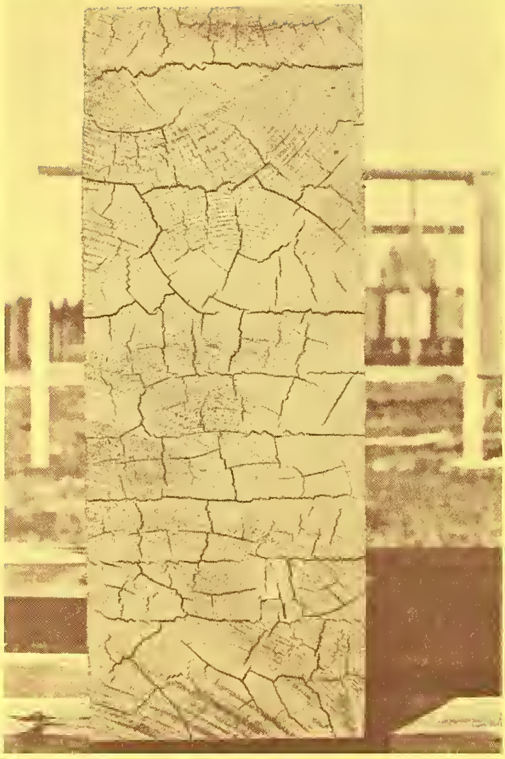

Figure 8.--End checking in 1B after 4 months.

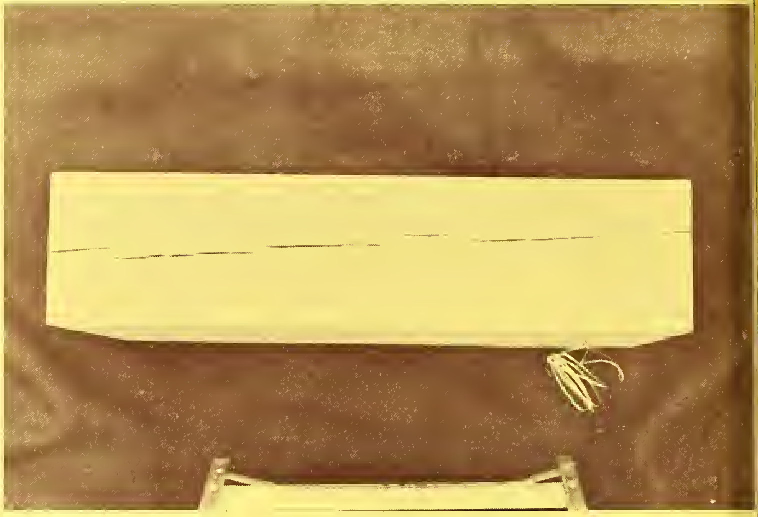

Figure 9.--Checks in top of 1A after 9 months.

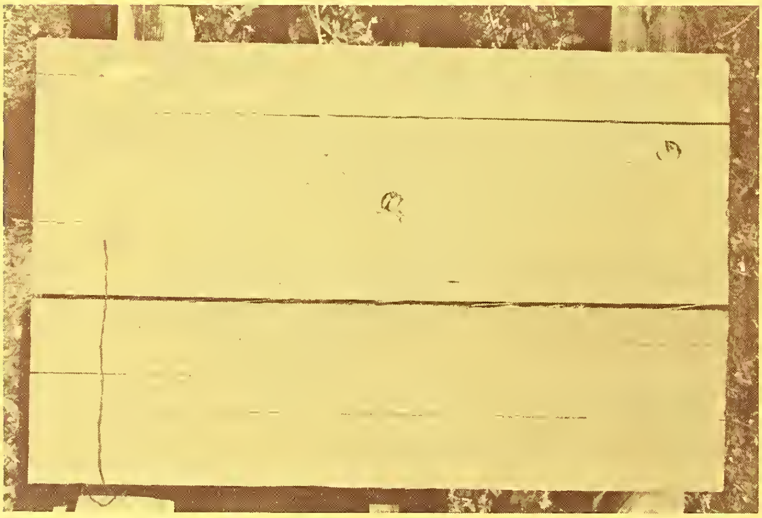

Figure 10.--Deep split in east side of 1B in less than 2 years.

The varnish systems, samples 4A and 4B and 9A and 9B, quickly showed evidence of failure also. The Timberlab varnish (4A and 4B), an experimental varnish developed by a British Government laboratory, showed slight end checking in 3 months, with water-staining appearing under the varnish near edges in another 6 months, a completely unsatisfactory appearance and unsatisfactory protective coating resulting within the first year (fig. 11). This varnish was designed to screen out the ultraviolet rays of the sun and extend the coating's life, but failure occurred because water seeped under the varnish at the sharp edges where the coating was thin. The same mode of failure developed in an equal time in the clear acrylic varnish (9A and 9B), but an interesting difference appears on the end grain surfaces, where the good end-sealing qualities of this varnish prevented any end checking during the entire 2-year exposure (figs. 12 and 13).

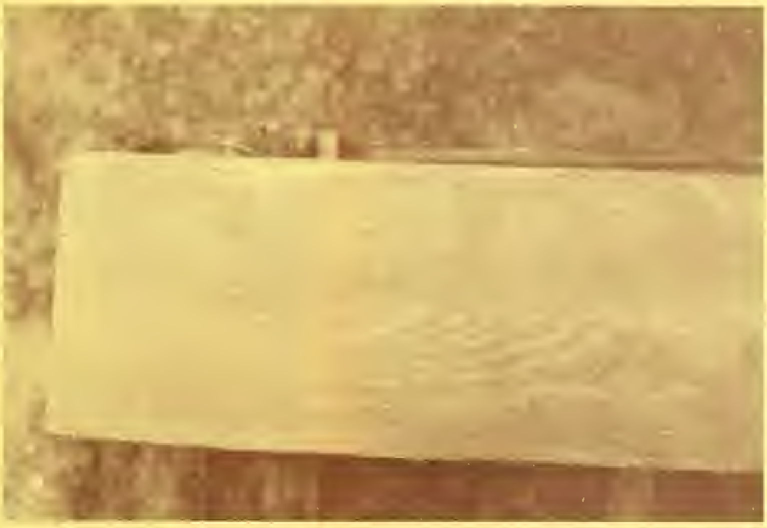

Figure 11.--Water staining under varnish at top of 4B after 9 months.

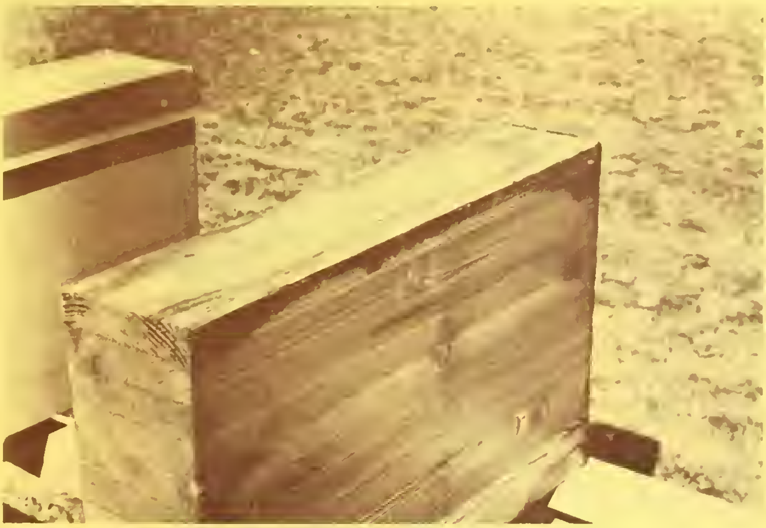

Figure 12.--Water staining under varnish in 9A after about 16 months.

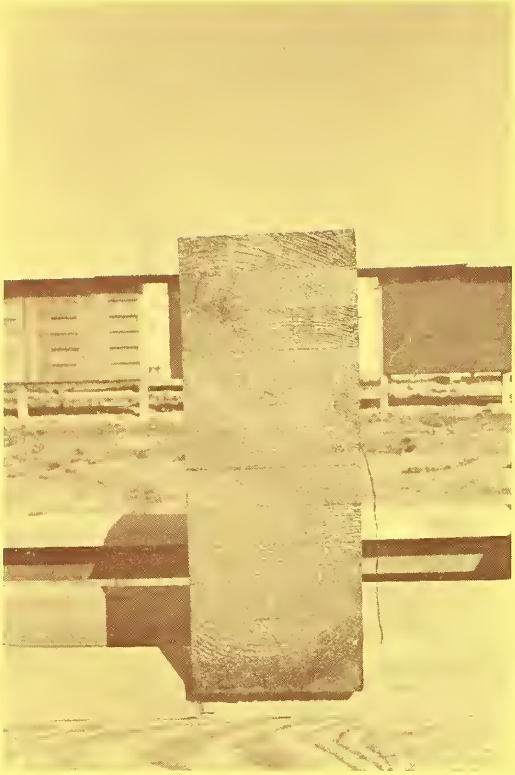

Figure 13.--Good moisture sealing at end prevented checking in 9A.

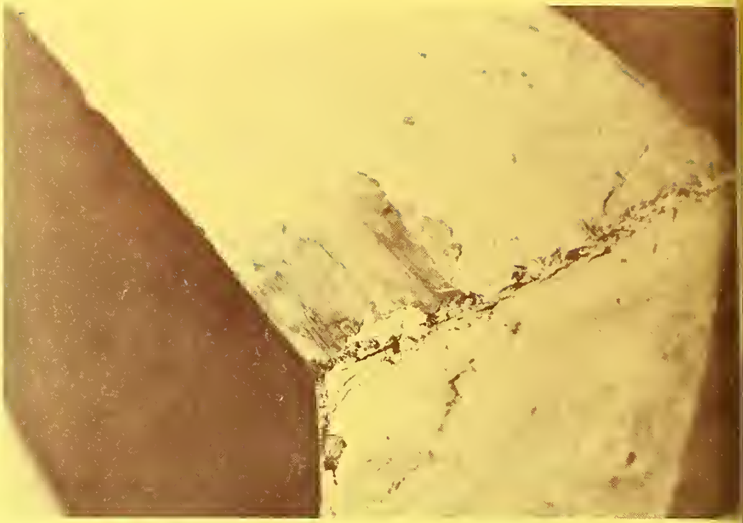

Figure 14.--Peeling of coating in 10A.

The troweled-on Neoprene coating (10A and 10B), lasted about a year before becoming brittle and cracked, allowing water to penetrate beneath it. It then began to lose its adhesion and peeled (fig. 14).

The only coating system to give outstanding promise of long life and virtually complete protection against water was the polyurea paint system (5A and 5B). After exposure for 3 years, there was no observable deterioration of this finish, and moisture contents in the wood remained very low through both wet and dry seasons (fig. 15).

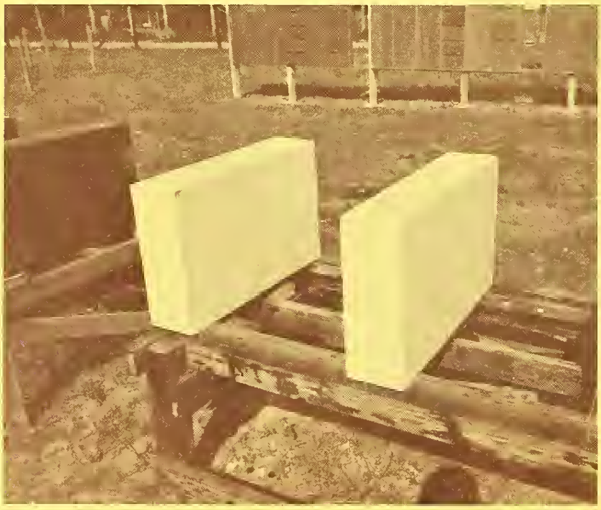

Figure 15.--Excellent appearance of 5A and 5B after 3 years.

The vinyl-based plastic flashing, reinforced with glass fiber (6A and 6B), appeared to be keeping the wood dry for about 6 months, but after this time some checking on side surfaces developed. After 3 more months, a large check developed in the side of sample 6B; and in another year, it became split along its entire length, tearing through both the flashing and the asphalt seal on the back (fig. 16). At the end of 34 months, tears also appeared at the end of sample 6A (fig. 17), suggesting that a tightly adhered flashing of this kind may not be an adequate solution for large beam sections.

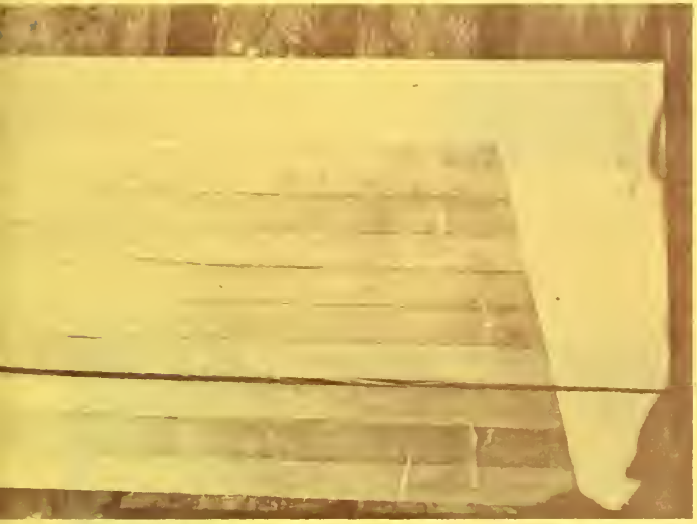

Figure 16.--Deep split in west side of 6B ruptures flashing.

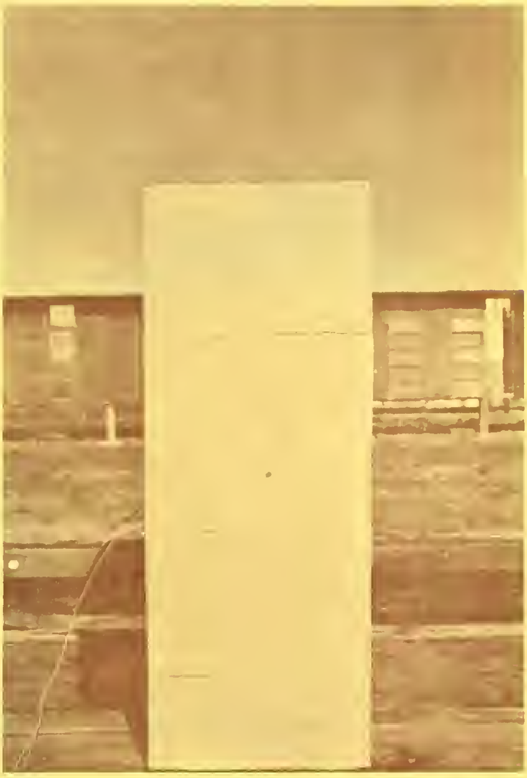

Figure 17.--Splitting of flashing at end of 6A.

The plywood covers in samples 3A and 3B, 7A and 7B, 11A and 11B, and 12A and 12B retained their integrity through the entire period of exposure, though the 3/8-inch unfinished redwood plywood on the first two sets of samples had some surface deterioration due to checking and some peeling of flat grain. The sample blocks swelled with moisture more than the plywood on the ends, so that a small crack opened at the top, under the top cover. This was protected, however, by the overhang of the top cover and probably had little effect. In sample 3B, some warping of the end cover also occurred, perhaps admitting wind-driven rain at the vertical edges. Although samples 3A and 3B had variable high moisture contents, all other plywood samples performed well in limiting moisture contents to low levels. Generally, this method of flashing may be recommended when it is carefully installed, but the better dimensional balance and resistance to warping of the five-ply 1/2-inch plywood suggest its superiority for this use (fig. 18). The plywood should also be finished for its protection, usually in the same manner as the beams.

The metal flashings (fig. 19) used on samples 8A and 8B also appear to have performed well in limiting high moisture contents, though several readings

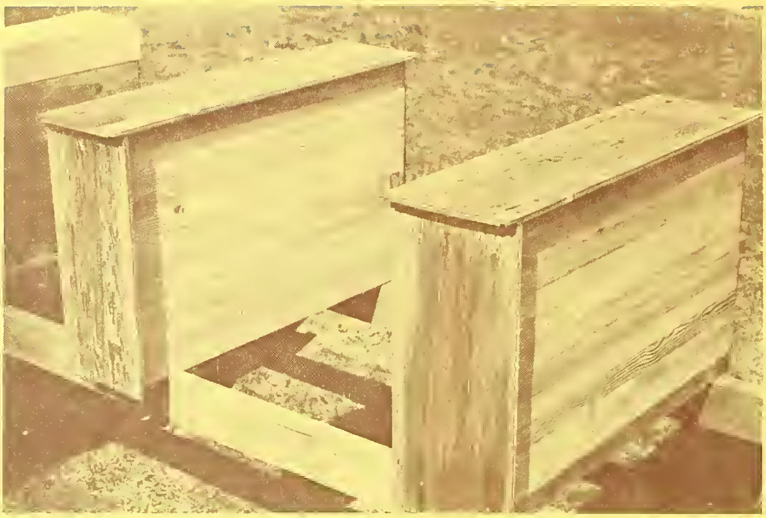

Figure 18.--Plywood covers on 7A and 7B.

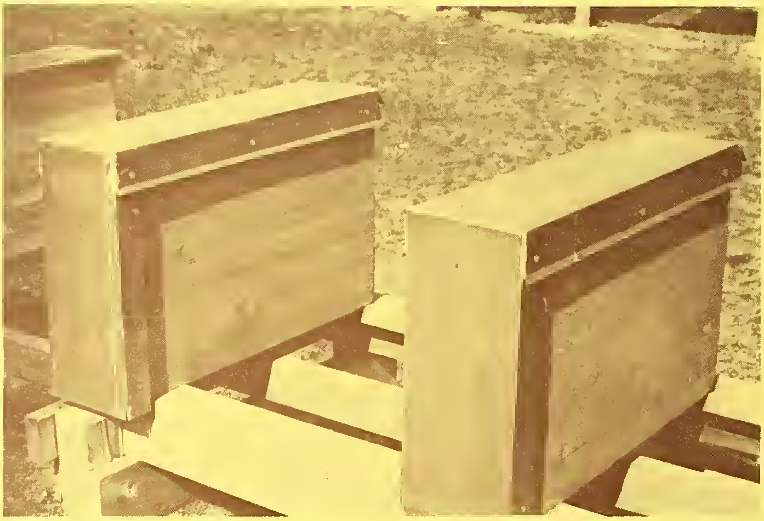

Figure 19.--Metal flashings on 8A and 8B.

indicate high levels. These occasional high levels do not persist for extended periods and probably do not present a decay hazard.

Although metal and plywood flashings were not removed for inspection of top and end surfaces, the side surfaces of all of these samples were free of any major checking, indicating that moisture contents did not vary widely. Some raised grain occurred, but the side checking found in other samples did not appear.

CONCLUSIONS

1. Of the six coating systems evaluated, only the polyurea paint used on samples 5A and 5B completely sealed and protected the wood and maintained excellent surface appearance for the 3-year duration of the study.

2. Flashings or covers of metal and plywood can be designed to limit moisture content to reasonable levels, thus protecting exposed beam ends from decay and maintaining the surface appearance of the wood. Plywood end and top caps performed well and are relatively easy to apply with available carpenter labor.

3. The vinyl-based plastic flashing studied was neither flexible nor strong enough to resist the stresses due to moisture changes and gradually reached a condition of complete failure within the 3-year exposure period. Similar systems based on other elastomers require further evaluation, and no general conclusions for this type of flashing is implied.

* * * * * * *

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